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(54) **COVERAGE HOLE DETECTION APPARATUS AND METHOD**

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H04W 64/00	(2009.01)
H04L 12/26	(2006.01)
H04W 36/08	(2009.01)
H04W 36/30	(2009.01)
H04B 17/318	(2015.01)

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CPC ***H04W 36/32*** (2013.01); ***H04B 17/318*** (2015.01); ***H04L 43/0811*** (2013.01); ***H04W 36/08*** (2013.01); ***H04W 36/30*** (2013.01); ***H04W 64/00*** (2013.01)

(58) **Field of Classification Search**
USPC 455/432.1, 433, 435.2, 436–445,455/450–453, 456.1–456.3; 370/329, 330, 331, 370/333
See application file for complete search history.

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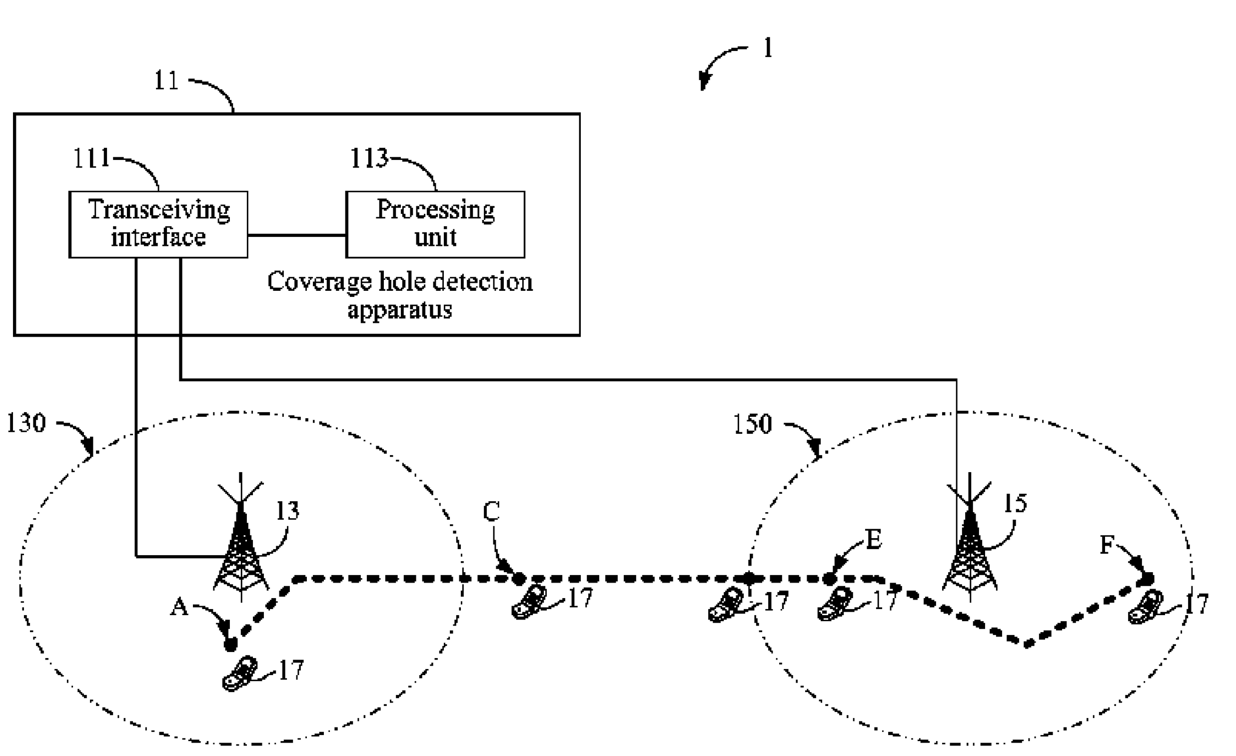
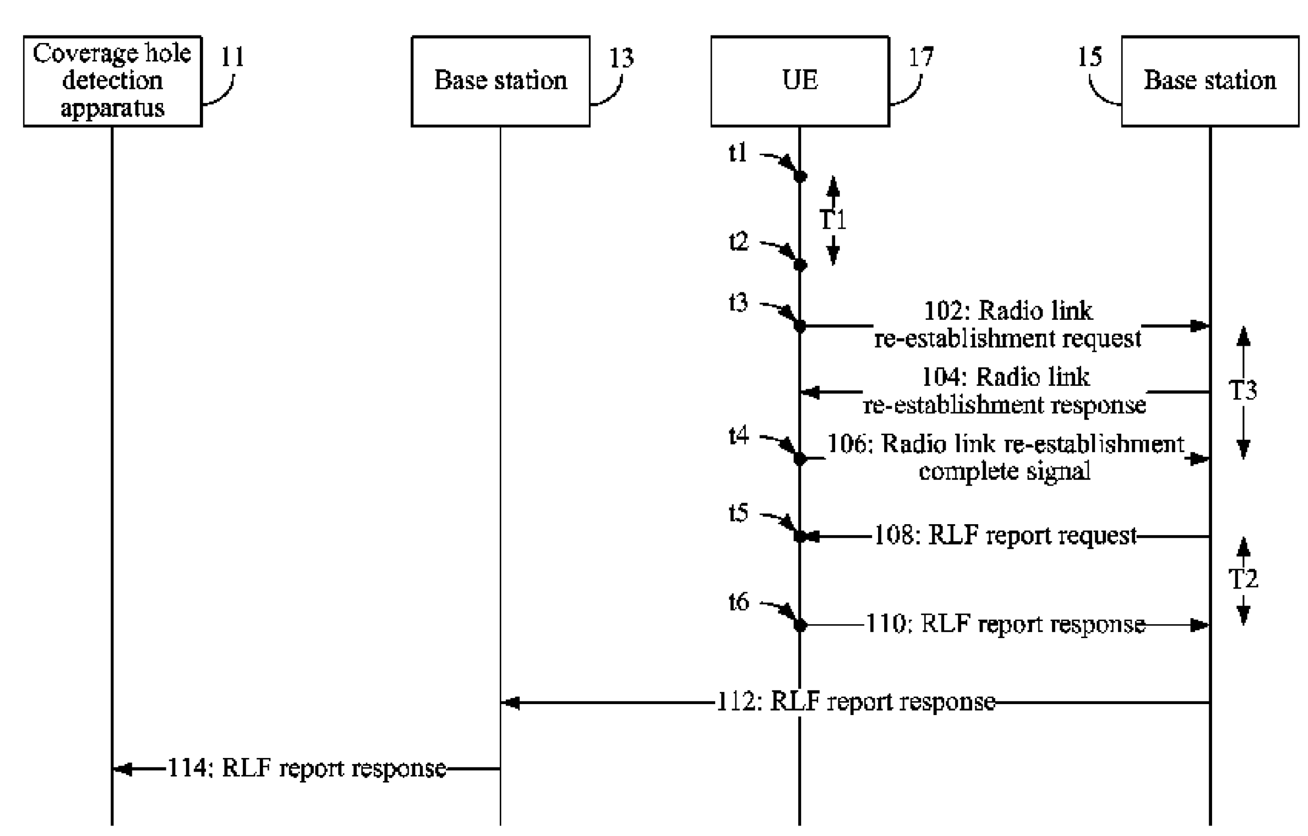
(57) **ABSTRACT**

A coverage hole detection apparatus and method are provided. The coverage hole detection apparatus decides two boundary locations of a coverage hole according to (a) a time length from a time point when a user equipment (UE) has detected a disconnection from a first base station to a time point when the UE determines that a Radio Link Failure (RLF) has happened, (b) a time length from a time point when the UE receives an RLF report request from a second base station to a time point when the UE transmits an RLF report response to the second base station, (c) a location that the UE determines that the RLF has happened, and (d) a location where the UE transmits the RLF report response. The coverage hole detection apparatus decides the coverage hole according to the two boundary locations and a sensitivity range of the UE.

12 Claims, 7 Drawing Sheets





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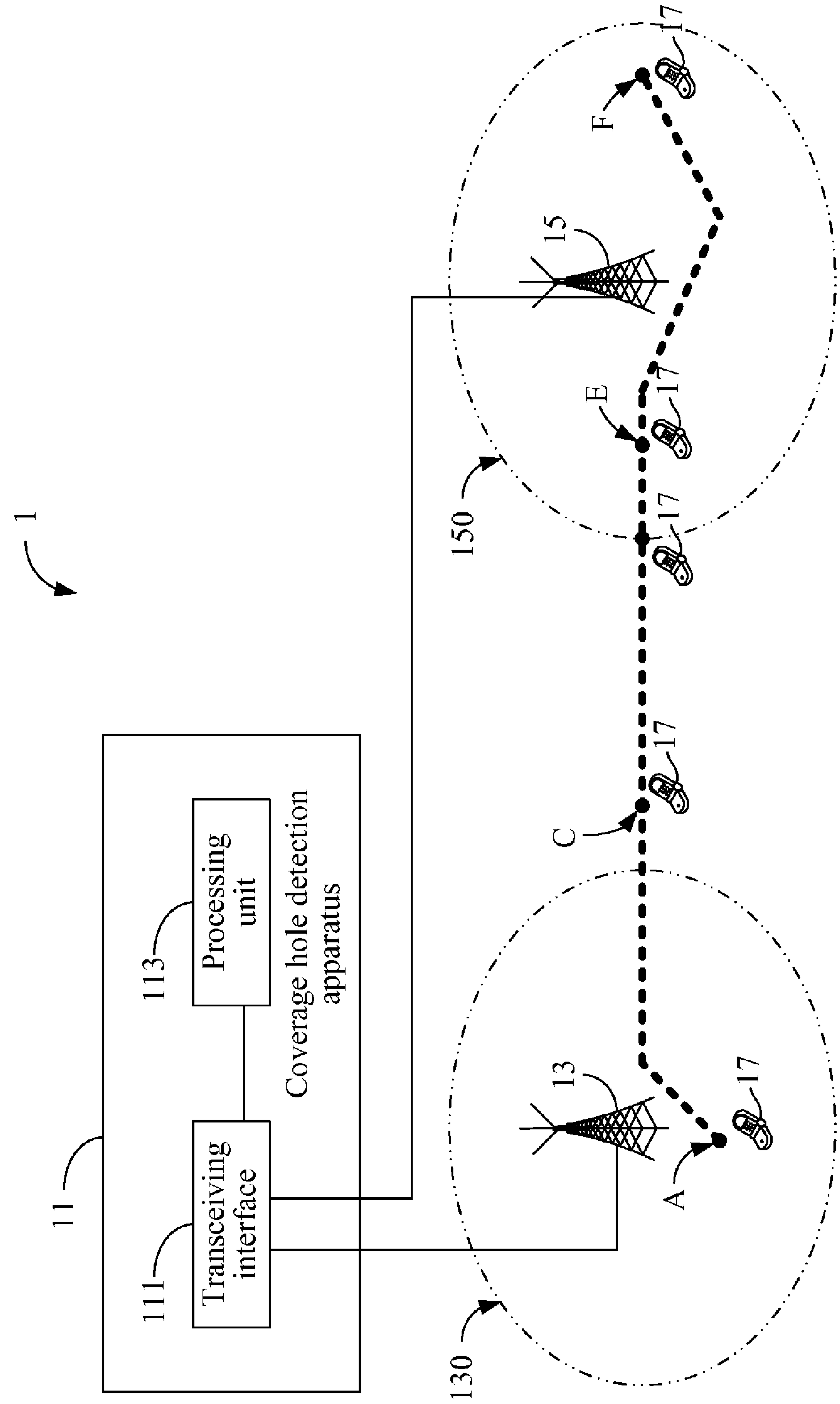
1
11
111
Transceiving interface
113
Processing unit
Coverage hole detection apparatus
13
15
17
130
150
A
C
E
F

FIG. 1A

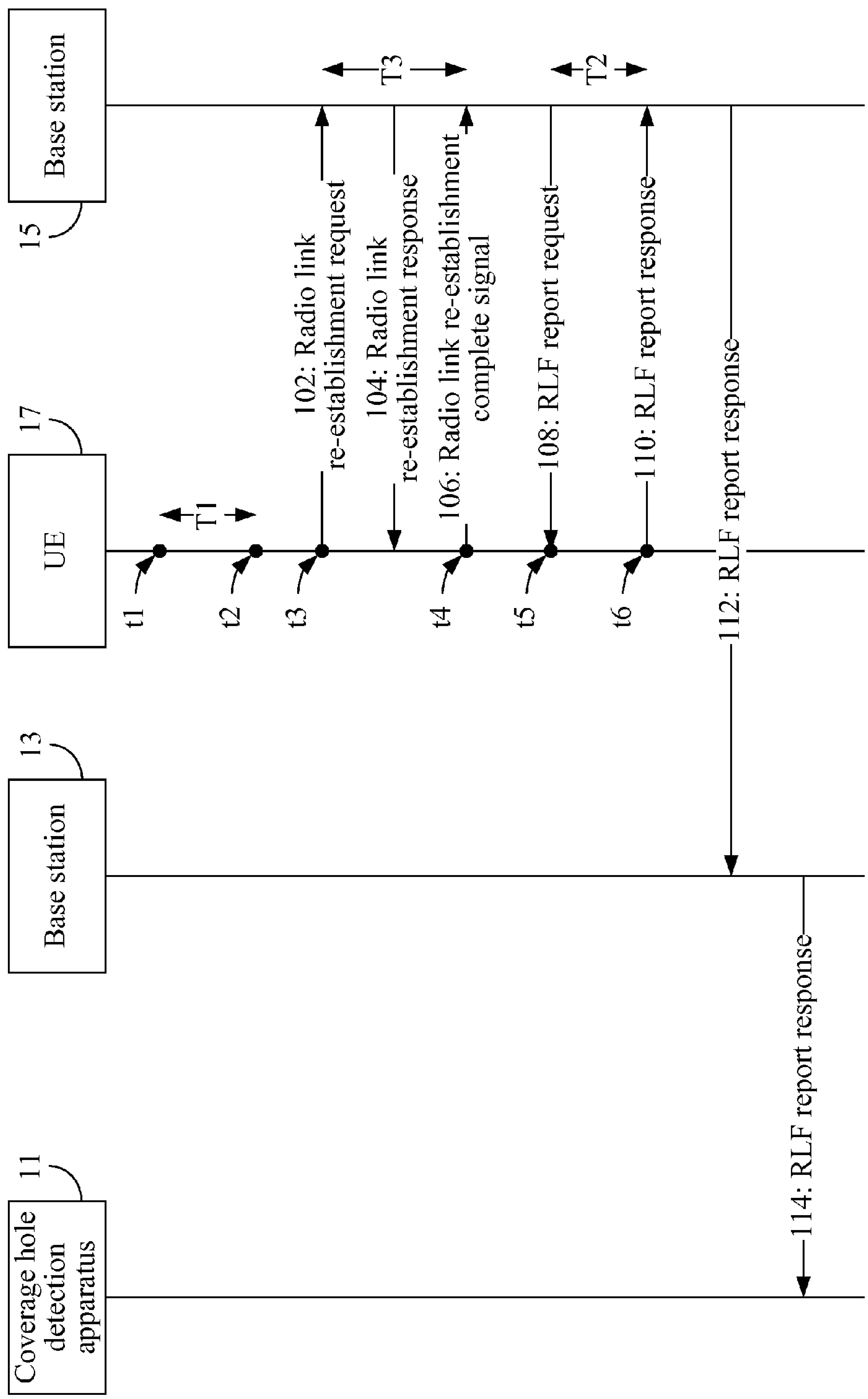
Base station
15
UE
17
Base station
13
Coverage hole detection apparatus
11
T1
T2
T3
t1
t2
t3
t4
t5
t6
102: Radio link re-establishment request
104: Radio link re-establishment response
106: Radio link re-establishment complete signal
108: RLF report request
110: RLF report response
112: RLF report response
114: RLF report response

FIG. 1B

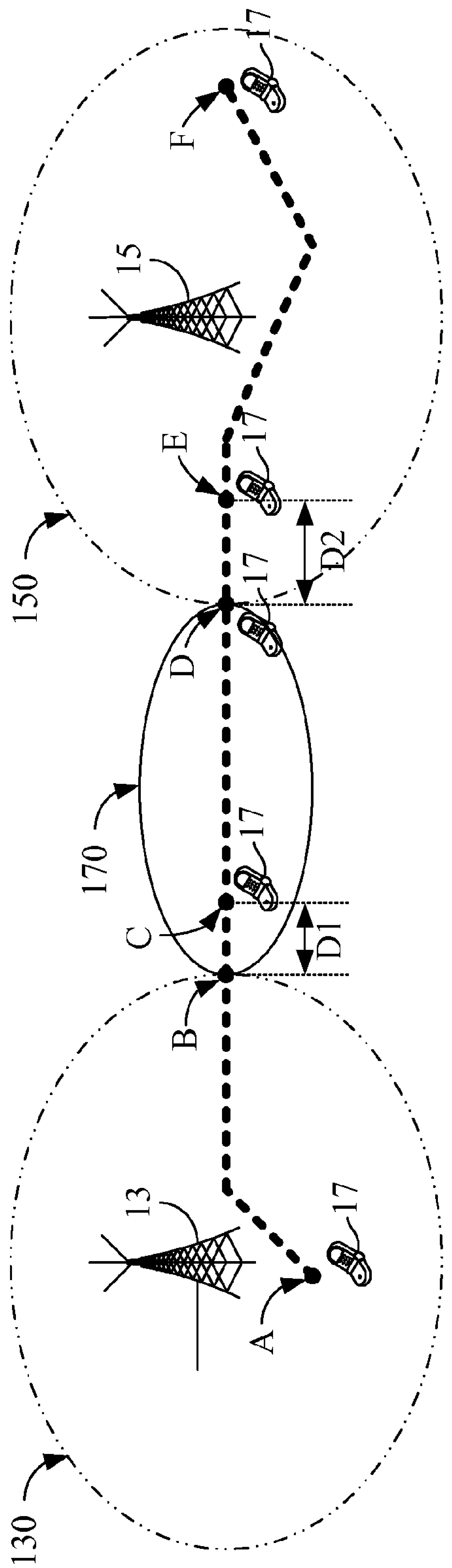

FIG. 1C

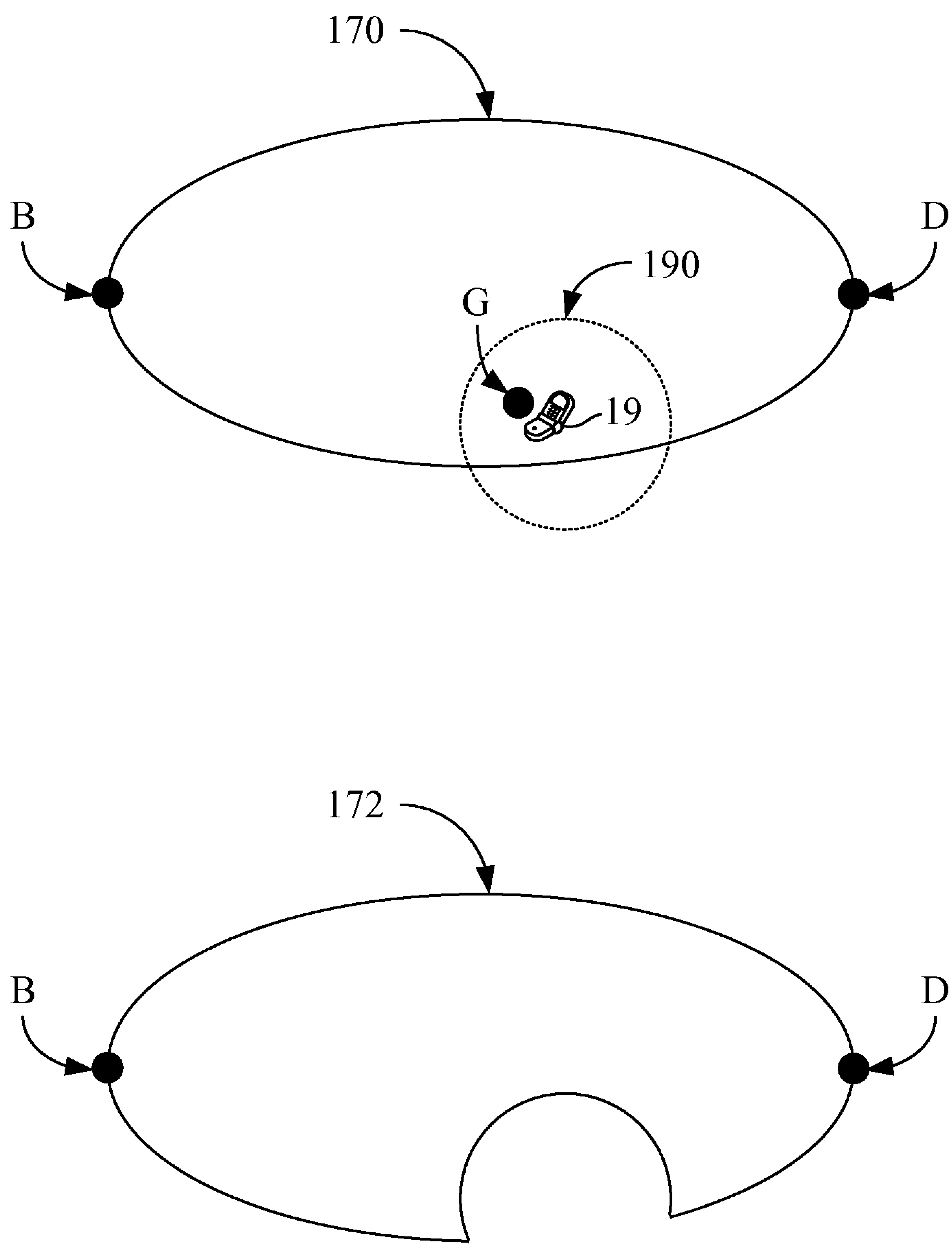

FIG. 1D

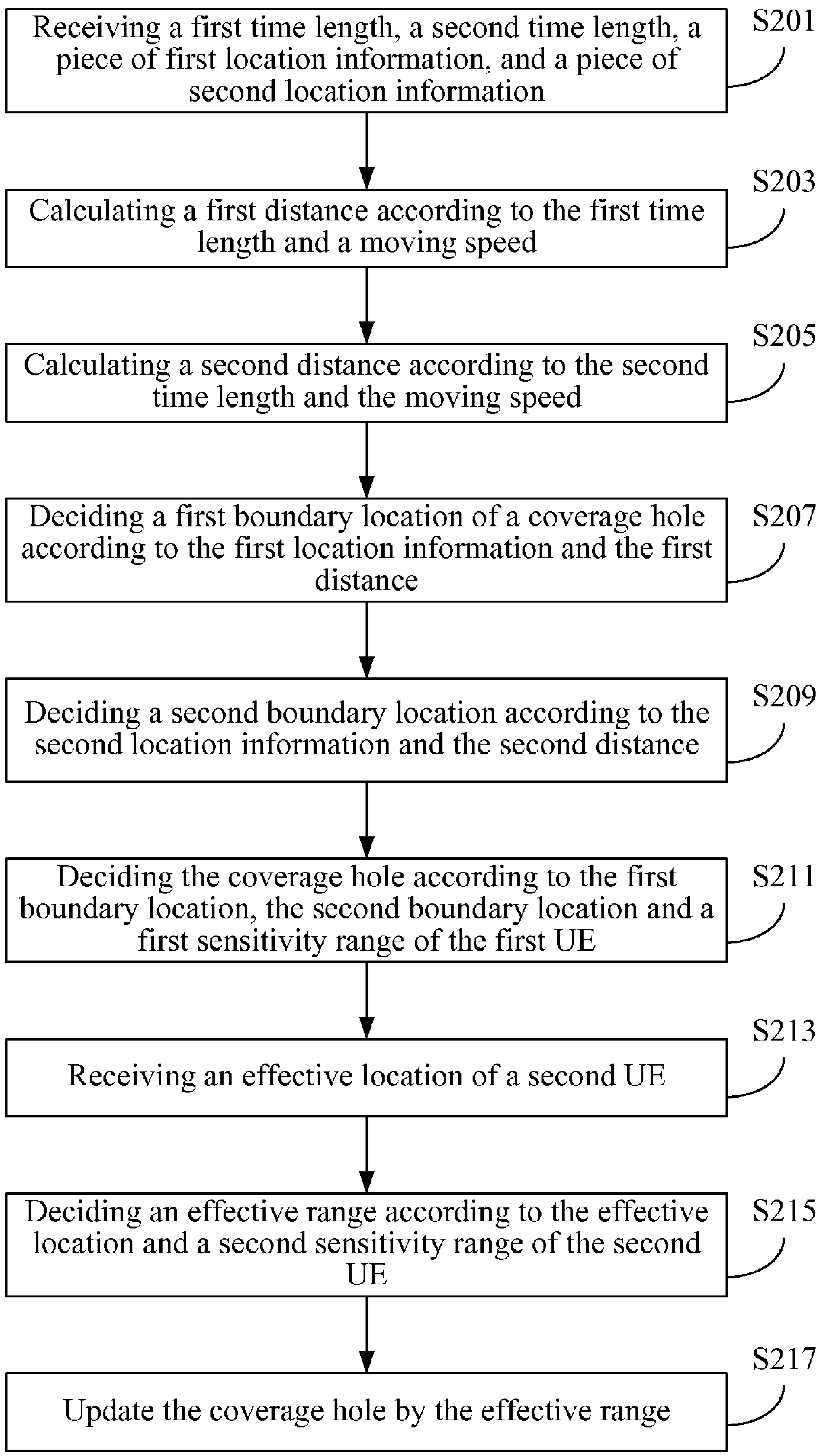
Receiving a first time length, a second time length, a piece of first location information, and a piece of second location information
S201
Calculating a first distance according to the first time length and a moving speed
S203
Calculating a second distance according to the second time length and the moving speed
S205
Deciding a first boundary location of a coverage hole according to the first location information and the first distance
S207
Deciding a second boundary location according to the second location information and the second distance
S209
Deciding the coverage hole according to the first boundary location, the second boundary location and a first sensitivity range of the first UE
S211
Receiving an effective location of a second UE
S213
Deciding an effective range according to the effective location and a second sensitivity range of the second UE
S215
Update the coverage hole by the effective range
S217

FIG. 2

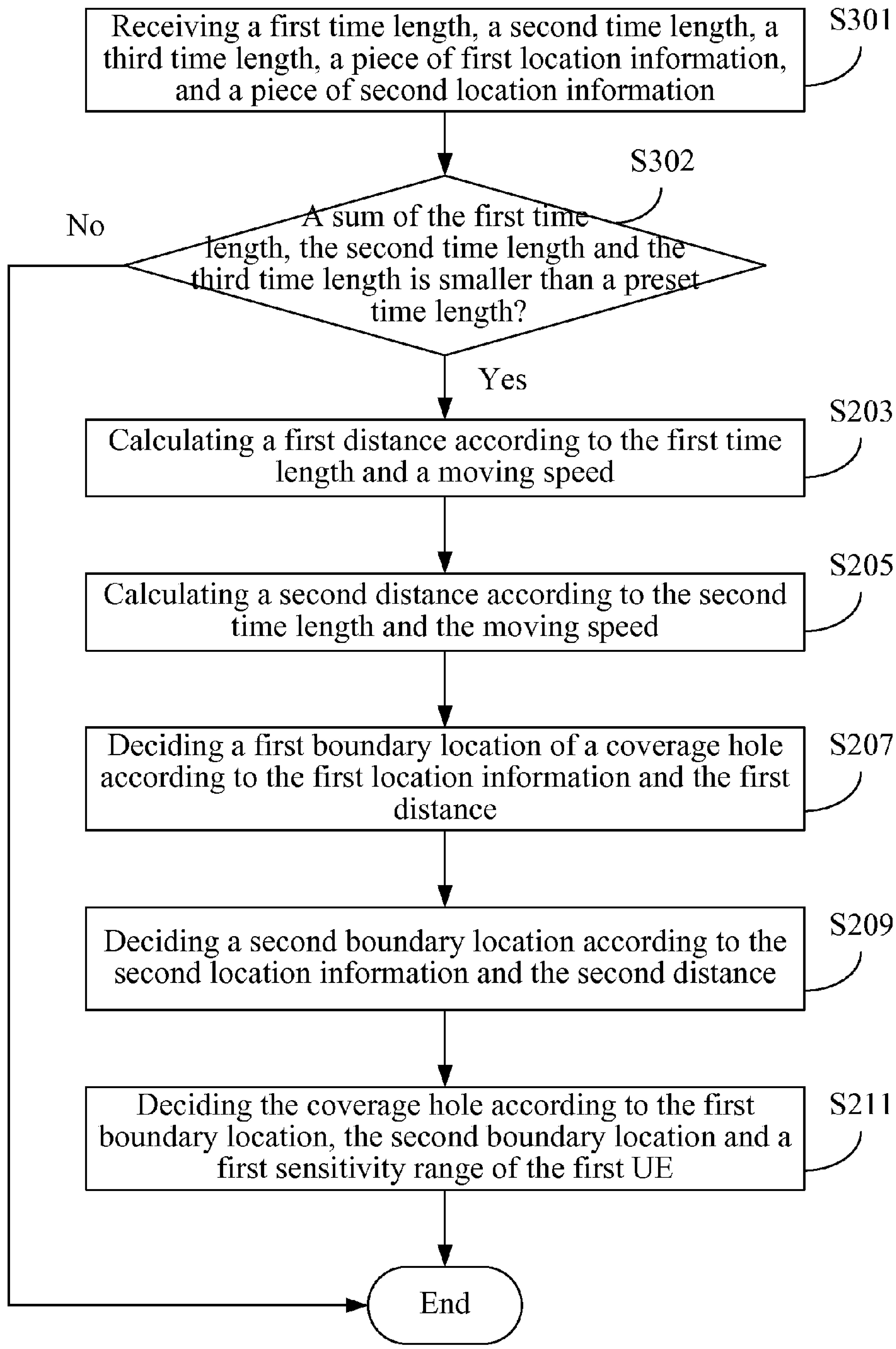
Receiving a first time length, a second time length, a third time length, a piece of first location information, and a piece of second location information
S301
S302
A sum of the first time length, the second time length and the third time length is smaller than a preset time length?
No
Yes
Calculating a first distance according to the first time length and a moving speed
S203
Calculating a second distance according to the second time length and the moving speed
S205
Deciding a first boundary location of a coverage hole according to the first location information and the first distance
S207
Deciding a second boundary location according to the second location information and the second distance
S209
Deciding the coverage hole according to the first boundary location, the second boundary location and a first sensitivity range of the first UE
S211
End

FIG. 3

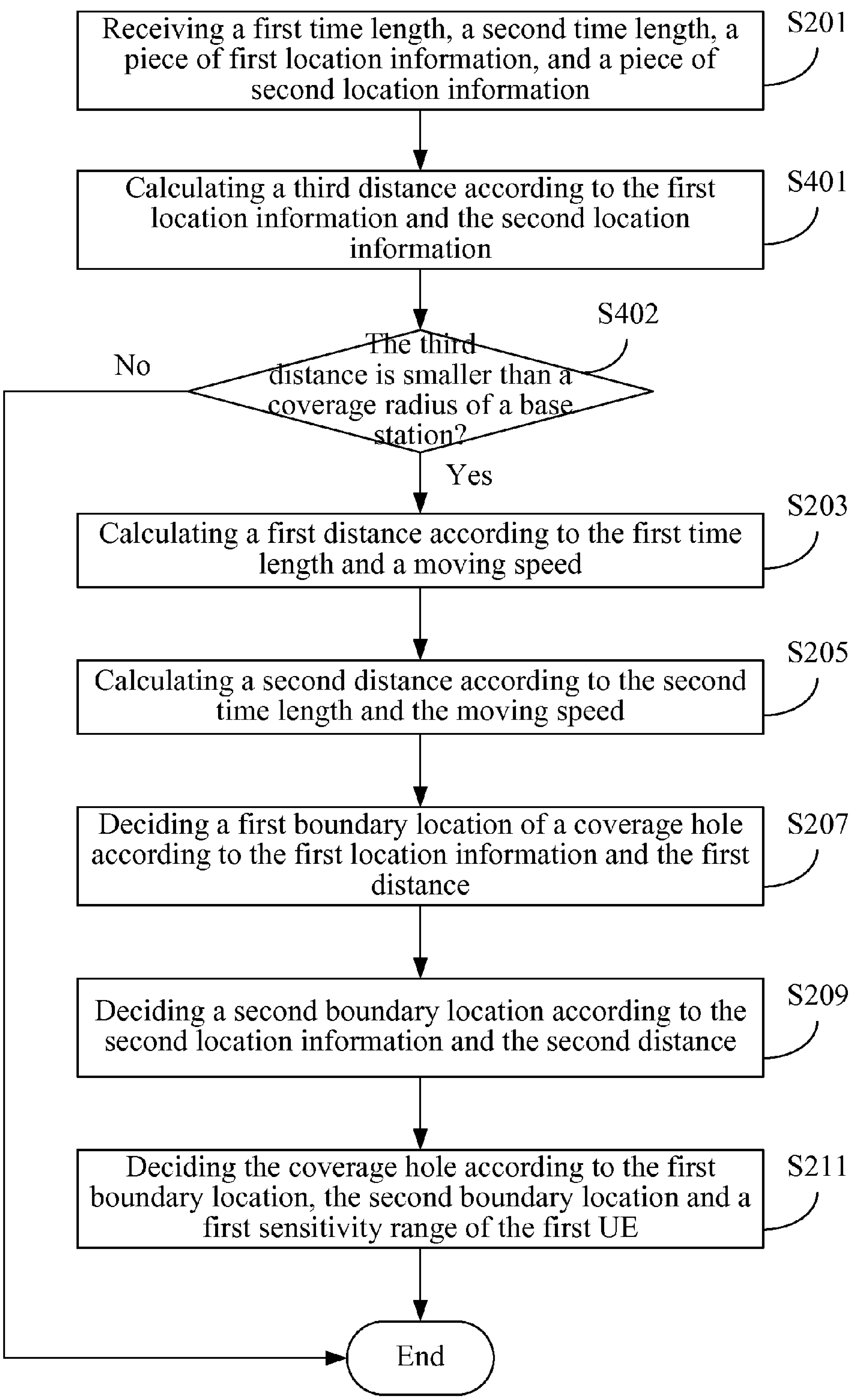
Receiving a first time length, a second time length, a piece of first location information, and a piece of second location information
S201
Calculating a third distance according to the first location information and the second location information
S401
The third distance is smaller than a coverage radius of a base station?
S402
No
Yes
Calculating a first distance according to the first time length and a moving speed
S203
Calculating a second distance according to the second time length and the moving speed
S205
Deciding a first boundary location of a coverage hole according to the first location information and the first distance
S207
Deciding a second boundary location according to the second location information and the second distance
S209
Deciding the coverage hole according to the first boundary location, the second boundary location and a first sensitivity range of the first UE
S211
End

FIG. 4

COVERAGE HOLE DETECTION APPARATUS AND METHOD

PRIORITY

This application claims priority to Taiwan Patent Application No. 104138480 filed on Nov. 20, 2015, which is hereby incorporated by reference in its entirety.

FIELD

The present invention relates to a coverage hole detection apparatus and method; more particularly, the present invention relates to a coverage hole detection apparatus and method that uses timing information and location information.

BACKGROUND

The wireless network communication technologies have experienced rapid development in recent years. To serve more users and to provide better communication quality, operators have to consider the integrity of base station deployment (e.g., whether the overall signal coverage of all base stations deployed has any coverage hole or whether mobile apparatuses will experience a poor received signal strength in some areas).

To overcome these problems, the operators used to make drive tests through use of many professionals to inspect the integrity of the base station coverage and then adjust the deployment of base stations (e.g., increase the number of base stations, adjust the antenna orientations of the base stations and etc.) according to the test results. However, making the drive tests by the professionals represents an overly high cost.

To reduce the cost of drive tests, the 3rd Generation Partnership Project (3GPP) standard utilizes the Radio Link Failure (RLF) report mechanism. Specifically, mobile apparatuses used by consumers are considered as the tools for drive tests in 3GPP. If a mobile apparatus experiences an RLF during the moving process, RLF related information (e.g., a previous serving base station of the mobile apparatus, a neighboring base station of the serving base station, the location of the serving base station and etc.) is transmitted to a backhaul network to evaluate the integrity of the base station coverage. Nevertheless, the 3GPP does not specify how to determine whether there is any coverage hole in the signal coverage of the wireless network system, so there is still a need for a coverage hole detection mechanism.

SUMMARY

The disclosure includes a coverage hole detection apparatus, which comprises a transceiving interface and a processing unit electrically connected with the transceiving interface. The transceiver interface is configured to receive a first time length, a second time length, a piece of first location information, and a piece of second location information. The first time length is from a time point when a user equipment (UE) has detected a disconnection from a first base station to a time point when the UE determines that a Radio Link Failure (RLF) has happened. The second time length is from a time point when the UE receives an RLF report request from a second base station to a time point when the UE transmits an RLF report response to the second base station. The piece of first location information indicates a location where the UE determines that the RLF has happened. The piece of second location information indicates a location where the UE transmits the RLF report response. The processing unit is configured to calculate a first distance according to the first time length and a moving velocity, calculate a second distance according to the second time length and the moving velocity, decide a first boundary location of a coverage hole according to the piece of first location information and the first distance, decide a second boundary location according to the piece of second location information and the second distance, and decide the coverage hole according to the first boundary location, the second boundary location, and a sensitivity range of the UE.

The disclosure also includes a coverage hole detection method for use in an electronic apparatus. The coverage hole detection method comprises the following steps of: (a) receiving a first time length, a second time length, a piece of first location information, and a piece of second location information, wherein the first time length is from a time point when a UE has detected a disconnection from a first base station to a time point when the UE determines that an RLF has happened, the second time length is from a time point when the UE receives an RLF report request from a second base station to a time point when the UE transmits an RLF report response to the second base station, the piece of first location information indicates a location where the UE determines that the RLF has happened, and the piece of second location information indicates a location where the UE transmits the RLF report response, (b) calculating a first distance according to the first time length and a moving velocity, (c) calculating a second distance according to the second time length and the moving velocity, (d) deciding a first boundary location of a coverage hole according to the piece of first location information and the first distance, (e) deciding a second boundary location according to the piece of second location information and the second distance, and (f) deciding the coverage hole according to the first boundary location, the second boundary location, and a first sensitivity range of the UE.

In certain embodiments, a first time length (i.e., a time length from a time point when a UE has detected a disconnection from a first base station to a time point when the UE determines that an RLF has happened) and a piece of first location information (i.e., the location where the UE determines that the RLF has happened) are used to calculate a first boundary location (i.e., a location where the UE has detected the disconnection from the first base station). Furthermore, a second time length (i.e., a time length from a time point when the UE receives an RLF report request from a second base station to a time point when the UE transmits an RLF report response to the second base station) and a piece of second location information (i.e., a location where the UE transmits the RLF report response) are used to calculate a second boundary location (i.e., a location where the UE has just found the second base station through searching). Afterwards, a coverage hole is decided according to the first boundary location, the second boundary location, and a sensitivity range of the UE.

Since the first boundary location corresponds to the location where the UE has detected a disconnection from the first base station and the second boundary location corresponds to the location where the UE has just found the second base station through searching, the coverage hole decided according to these two boundary locations and the sensitivity range of the UE is surely an area where it is impossible or difficult for the UE to be served by a base station. Moreover, the present invention may further refer to

time information and geographic information to decide the coverage hole more correctly.

The detailed technology and preferred embodiments implemented for the subject invention are described in the following paragraphs accompanying the appended drawings for people skilled in this field to well appreciate the features of the claimed invention.

BRIEF DESCRIPTION OF THE DRAWINGS

FIG. **1**A is a schematic view illustrating an architecture of a wireless network system **1** of a first embodiment;

FIG. **1**B is a schematic view illustrating signal transmissions between a coverage hole detection apparatus **11**, a base station **13**, a base station **15**, and a UE **17**;

FIG. **1**C is a schematic view illustrating how the coverage hole detection apparatus **11** decides a coverage hole **170**;

FIG. **1**D is a schematic view illustrating updating the coverage hole **170** by the effective range;

FIG. **2** is a flowchart diagram of a second embodiment;

FIG. **3** is a flowchart diagram of a third embodiment; and

FIG. **4** is a flowchart diagram of a fourth embodiment.

DETAILED DESCRIPTION

In the following description, a coverage hole detection apparatus and method of the present invention will be explained with reference to example embodiments thereof. However, these example embodiments are not intended to limit the present invention to any specific examples, embodiments, environment, applications, or particular implementations described in these example embodiments. Therefore, description of these example embodiments is only for purpose of illustration rather than to limit the present invention. It should be appreciated that elements unrelated to the present invention are omitted from depiction in the following embodiments and the attached drawings.

A first embodiment of the present invention is a wireless network system **1** and a schematic view of an architecture of the wireless network system **1** is shown in FIG. **1**A. The wireless network system **1** comprises a coverage hole detection apparatus **11**, two base stations **13**, **15**, and a UE **17**. The base station **13** has a signal coverage **130**, while the base station **15** has a signal coverage **150**. It shall be appreciated that the present invention does not limit the number of base stations that can be comprised in a wireless network system. The present invention does not limit the number of UEs that can be served by one base station as well. Moreover, a person having ordinary skill in the art shall appreciate that the UE may be any mobile apparatus capable of communicating with a base station.

The coverage hole detection apparatus **11** comprises a transceiving interface **111** and a processing unit **113**, wherein the transceiving interface **111** is electrically connected to the processing unit **113**. The processing unit **113** may be any of various processors, central processing units (CPUs), microprocessors, or other computing devices well known to those of ordinary skill in the art. The transceiving interface **111** may be any interface capable of establishing a communication connection with a base station. In this embodiment, the coverage hole detection apparatus **11** is a server, so the transceiving interface **111** connects to the base stations **13**, **15** in a wired way (e.g., through twisted pair cables, optical cables, or co-axial electrical cables). In other embodiments, the coverage hole detection apparatus **11** may be a base station and the transceiving interface **11** may connect to the base stations either in a wired or wireless way (e.g., through antennas of the base stations).

In this embodiment, the UE **17** is moved from a location A to a location F along a movement path as shown by a thick solid line in FIG. **1**A. It shall be appreciated that the movement path shown in FIG. **1**A is only for purpose of illustration and is not to limit the scope of the present invention. A Radio Link Failure (RLF) happens during the process of moving the UE **17** from the location A to the location F. The coverage hole detection apparatus **11** will use information related to the RLF to detect a coverage hole.

Please refer to FIG. **1**B as well, which is a schematic view illustrating signal transmissions between the coverage hole detection apparatus **11**, the base stations **13**, **15**, and the UE **17** during the process of moving the UE **17** from the location A to the location F.

The signal strength of a base station attenuates as the distance increases. Therefore, a disconnection from the base station **13** will happen when the UE **17** is moved to a boundary of the signal coverage **130** of the base station **13**. In this embodiment, the UE **17** detects a disconnection with the base station **13** (i.e., the UE **17** cannot connect to the base station **13** anymore) at a time point t**1**, so the UE **17** activates a first timer. At a time point t**2** (i.e. the time point right after the time has elapsed for a first preset time length), the UE **17** detects that it is still disconnected from the base station **13**. Since the UE **17** has been disconnected from the base station **13** for the first preset time length, the UE **17** determines that an RLF has happened. When the UE **17** determines that an RLF has happened (i.e., at the time point t**2**), the UE **17** stops the first timer and records a piece of first location information (i.e., the location C shown in FIG. **1**A) where the UE **17** is located at this time point (i.e., at the time point when it is determined that an RLF has happened). Based on the aforesaid operations made by the UE **17** on the first timer, the first timer records a time length T**1** from the time point when the UE **17** detects a disconnection from the base station **13** to the time point when the UE **17** determines that an RLF has happened.

Since the UE **17** has determined that an RLF has happened, the UE **17** searches for other base stations that it can connect to. In this embodiment, the base station **15** is found by the UE **17** through searching at a time point t**3**, so the UE **17** performs a radio link re-establishment procedure with the base station **15**. Specifically, the UE **17** transmits a radio link re-establishment request **102** to the base station **15**, the base station **15** transmits a radio link re-establishment response **104** to the UE **17** in response. In response to the radio link re-establishment response **104**, the UE **17** transmits a radio link re-establishment complete signal **106** to the base station **15**. Through the 3-way handshakes, the radio link re-establishment procedure can be completed between the UE **17** and the base station **15**.

Tue UE **17** receives an RLF report request **108** transmitted by the base station **15** at a time point t**5**, so the UE **17** activates a second timer. The purpose of transmitting the RLF report request **108** by the base station **15** is to request for RLF related information from the UE **17**. At a time point t**6**, the UE **17** has prepared the RLF related information (e.g., an identity of a previous base station (i.e., the base station **13**) of the UE **17**, an identity of a neighboring base station of the previous base station, location information of the previous base station, etc) for the base station **15**, so the UE **17** records a piece of second location information about the location (i.e., the location E shown in FIG. **1**A) where it is located at the time point **6**, transmits an RLF report response **110** to the base station **15**, and stops the second timer.

It shall be appreciated that the time point t**6** may also be treated as a time point when the RLF report response **110** is transmitted by the UE **17** and the piece of second location information may be viewed as a location where the RLF report response **110** is transmitted by the UE **17**. Additionally, based on the aforesaid operations on the second timer by the UE **17**, the second timer records a time length T**2** from the time point when the RLF report request **108** is received by the UE **17** to the time point when the RLF report response **110** is transmitted by the UE **17** to the base station **15**. Furthermore, the RLF report response **110** carries the RLF related information, the piece of first location information (i.e., the location C shown in FIG. **1**A), the piece of second location information (i.e., the location E shown in FIG. **1**A), the time length T**1**, and the time length T**2**.

Afterwards, the base station **15** transmits an RLF report response **112** to the base station **13**. Similarly, the RLF report response **112** carries the RLF related information, the piece of first location information (i.e., the location C shown in FIG. **1**A), the piece of second location information (i.e., the location E shown in FIG. **1**A), the time length T**1**, and the time length T**2**. Next, the base station **13** transmits an RLF report response **114** to the coverage hole detection apparatus **11**. Similarly, the RLF report response **114** carries the RLF related information, the piece of first location information (i.e., the location C shown in FIG. **1**A), the piece of second location information (i.e., the location E shown in FIG. **1**A), the time length T**1**, and the time length T**2**.

In this embodiment, each of the UE **17**, the base station **13**, and the base station **15** integrates the RLF related information, the piece of first location information, the piece of second location information, the time length T**1**, and the time length T**2** into one single signal (i.e., the RLF report responses **110**, **112**, **114**) for transmission. However, it is noted that the UE **17** may transmit the RLF related information, the piece of first location information, the piece of second location information, the time length T**1**, and the time length T**2** individually in other embodiments and so do the base station **15** and the base station **13**.

From the viewpoint of the coverage hole detection apparatus **11**, the transceiving interface **111** receives the piece of first location information (i.e., the location C), the piece of second location information (i.e., the location E), the time length T**1**, and the time length T**2** from the base station **13**. Please refer to FIG. **1**C as well, which is a schematic view illustrating how the coverage hole detection apparatus **11** decides a coverage hole **170**. The processing unit **113** calculates a first distance D**1** according to the time length T**1** (i.e., the time length from a time point when the UE **17** has detected a disconnection from the base station **13** to a time point when the UE **17** determines that an RLF has happened) and a moving velocity. Furthermore, the processing unit **113** calculates a second distance D**2** according to the time length T**2** (i.e., a time length from a time point when the UE **17** receives the RLF report request **108** to a time point when the UE **17** transmits the RLF report response **110** to the base station **15**) and a moving velocity. It shall be appreciated that the moving velocity may be a preset value, an average moving velocity of general UEs, a history average moving velocity of the UE **17**, or some other similar values.

Afterwards, the processing unit **113** decides a first boundary location (i.e., the location B) of the coverage hole **170** according to the piece of first location information (i.e., the location C) and the first distance D**1**. Specifically, the processing unit **113** takes the piece of first location information (i.e., the location C**1**) as a start point and calculates a location (i.e., the location B) having a distance D**1** backward from the start point on the movement path of the UE **17** and the processing unit **113** takes this location as the first boundary location. In other words, the processing unit **113** calculates the first boundary location as the location where the UE **17** begins to detect a disconnection from the base station **13** according to the piece of first location information (i.e., the location C) and the first distance D**1**.

Moreover, the processing unit **113** decides a second boundary location (i.e., the location D) of the coverage hole **170** according to the piece of second location information (i.e., the location E) and the second distance D**2**. Specifically, the processing unit **113** takes the piece of second location information (i.e., the location E) as a start point and calculates a location (i.e., the location D) having a distance D**2** backward from the start point on the movement path of the UE **17** and the processing unit **113** takes this location as the second boundary location. In other words, the processing unit **113** calculates a location where the UE **17** finds the base station **15** through searching according to the piece of second location information (i.e., the location E) and the second distance D**2**.

Thereafter, the processing unit **113** decides a coverage hole **170** according to the first boundary location (i.e., the location B), the second boundary location (i.e., the location D), and a sensitivity range (not shown) of the UE **17**. Briefly speaking, the coverage hole detection apparatus **11** decides the coverage hole **170** according to the location where the UE **17** begins to detect a disconnection from the base station **13**, the location where the UE **17** finds the base station **15** through searching, and the sensitivity range of the UE **17**.

In some embodiments, the transceiving interface **111** of the coverage hole detection apparatus **11** also receives an effective location(s) transmitted by the UE **17** and/or other UEs. The transceiving interface **111** may receive the effective location(s) via the base station **13** and/or the base station **15**. An effective location refers to a location where an UE is able to receive signals transmitted by the base station **13** and/or the base station **15**. For an effective location, an effective range may be decided by the processing unit **113** according to the effective location and a sensitivity range of the UE that transmits the effective location. The processing unit **113** then updates the coverage hole **170** by the effective range. Here, a concrete example will be described with reference to FIG. **1**D. The transceiving interface **111** receives an effective location G transmitted by a UE **19** directly or via a base station. The processing unit **113** decides an effective range **190** according to the effective location G and the sensitivity range of the UE **19**. Then, the processing unit **113** calculates an overlapped area between the coverage hole **170** and the effective range **190**. The processing unit **113** updates the coverage hole **172** by deducting the overlapped area from the coverage hole **170**.

In some embodiments, the coverage hole detection apparatus **11** may further refer to other time information (i.e., the time length from the time point when the UE **17** finds the base station **15** through searching to the time point when the UE **17** completes the radio link re-establishment procedure with the base station **15**) to prevent from using erroneous information to calculate the coverage hole. Here, how this time information is obtained by the coverage hole detection apparatus **11** will be further described with reference to FIG. **1**A. When the base station **15** is found through searching by the UE **17** at the time point t**3**, the UE **17** activates a third timer. When the UE **17** transmits a radio link re-establishment complete signal **106** to the base station **15** at the time point t**4**, the UE **17** stops the third timer. Based on the aforesaid operations on the third timer by the UE **17**, the third timer records a time length T3 from the time point when the base station **15** is found through searching by the UE **17** to the time point when the UE **17** completes the radio link re-establishment procedure with the base station **15**. In these embodiments, the time length T3 is transmitted to the coverage hole detection apparatus **11**, e.g., by being carried in the RLF report response **110**, **112**, **114**. In these embodiments, after the time length T1, the time length T2, and the time length T3 are received by the transceiving interface **111**, the processing unit **113** determines whether a sum of the time length T1, the time length T2, and the time length T3 is smaller than a second preset time length. If the sum of the time length T1, the time length T2, and the time length T3 is not smaller than the second preset time length, it means that it is very likely that the UE **17** stays at a location having a poor signal strength for a long time and, hence, the processing unit **113** will not decide the coverage hole according to related information collected from this RLF. The processing unit **113** decides the coverage hole **170** through the aforesaid operations according to the piece of first location information, the piece of second location information, the time length T1, and the time length T2 only when the sum of the time length T1, the time length T2, and the time length T3 is smaller than the second preset time length.

In some embodiments, the coverage hole detection apparatus **11** may further make reference to other geographic information to prevent from using erroneous information to calculate the coverage hole. Specifically, the processing unit **113** may calculate a third distance (not shown) according to the piece of first location information (i.e., the location where the UE **17** determines that an RLF has happened—the location C) and the piece of second location information (i.e., the location where the UE **17** transmits the RLF report response **110**—the location E). The processing unit **113** determines whether the third distance is smaller than a coverage radius of a base station (e.g., the base station **13**). If the third distance is not smaller than the coverage radius of the base station, it means that it is very likely that the UE **17** rapidly presents in a signal coverage of another non-neighboring base station (e.g., in a flying airplane) and, hence, the processing unit will not decide the coverage hole according to related information collected from this RLF. The processing unit **113** decides the coverage hole **170** through the aforesaid operations according to the piece of first location information, the piece of second location information, the time length T1, and the time length T2 only when the third distance is smaller than a coverage radius of a base station.

In other embodiments, the transceiving interface **111** of the coverage hole detection apparatus **11** may further receive a Reference Signal Receiving Power (RSRP) and a Received Signal Strength Indicator (RSSI) that is transmitted by the UE **17** directly or via a base station. In these embodiments, the processing unit **113** decides the coverage hole **170** through the aforesaid operations according to the piece of first location information, the piece of second location information, the time length T1, and the time length T2 only when it is determined that the RSRP of the UE **17** is smaller than a first threshold and that the UE **17** does not perform a handover procedure. Additionally, the processing unit **113** decides a type of the coverage hole **170** according to the RSSI of the UE **17** and a second threshold. Specifically, the processing unit **113** decides the coverage hole **170** to be a coverage hole caused by interferences when the RSSI of the UE **17** is larger than the second threshold and to be a general coverage hole when the RSSI of the UE **17** is not larger than the second threshold.

According to the above descriptions, the first time length (i.e., a time length from a time point when the UE **17** has detected a disconnection from the base station **13** to a time point when the UE **17** determines that an RLF has happened) and the piece of first location information (i.e., the location where the UE **17** determines that the RLF has happened) are used to calculate a first boundary location (i.e., a location where the UE **17** has detected the disconnection between the UE **17** and the base station **13**). Further, the second time length (i.e., a time length from a time point when the UE **17** receives an RLF report request **108** from the base station **15** to a time point when the UE **17** transmits an RLF report response **110** to the base station **15**) and a piece of second location information (i.e., a location where the UE **17** transmits the RLF report response **110**) are used to calculate a second boundary location (i.e., a location where the base station **15** is detected by the UE **17**). Then, a coverage hole **170** is decided by the coverage hole detection apparatus **11** according to the first boundary location, the second boundary location, and a sensitivity range of the UE **17**. Since the first boundary location corresponds to the location where the UE **17** has detected a disconnection between the UE **17** and the base station **13** and the second boundary location corresponds to the location where the base station **15** is detected by the UE **17**, the coverage hole **170** decided according to these two boundary locations and the sensitivity range of the UE **17** is surely an area where it is impossible or difficult for the UE **17** to be served by a base station. Furthermore, the reference time information and the geographic information may also be used by the coverage hole detection apparatus **11** to derive the coverage hole **170** more correctly.

A second embodiment of the present invention is a coverage hole detection method and a flowchart diagram of which is shown in FIG. **2**. The coverage hole detection method is for use in an electronic apparatus, e.g., the coverage hole detection apparatus **11** described in the first embodiment.

First, step S**201** is executed to receive a first time length, a second time length, a piece of first location information, and a piece of second location information by the electronic apparatus. The first time length is from a time point when a first UE has detected a disconnection from a first base station to a time point when the first UE determines that an RLF has happened. The second time length is from a time point when the first UE receives an RLF report request from a second base station to a time point when the first UE transmits an RLF report response to the second base station. The piece of first location information indicates a location where the first UE determines that the RLF has happened. The piece of second location information indicates a location where the first UE transmits the RLF report response.

Then, step S**203** is executed to calculate a first distance according to the first time length and a moving velocity by the electronic apparatus. Step S**205** is executed to calculate a second distance according to the second time length and the moving velocity by the electronic apparatus. Step S**207** is executed to decide a first boundary location of a coverage hole by the electronic apparatus according to the piece of first location information and the first distance. Step S**209** is executed to decide a second boundary location by the electronic apparatus according to the piece of second location information and the second distance. It shall be appreciated that the steps S**203**, S**205**, S**207** and S**209** may be executed in other orders in other embodiments as long as the step S203 is executed earlier than the step S207 and the step S205 is executed earlier than the step S209. Afterwards, step S211 is executed to decide the coverage hole by the electronic apparatus according to the first boundary location, the second boundary location, and a first sensitivity range of the first UE.

In some embodiments, the coverage hole detection method may further execute step S213 for receiving an effective location of a second UE by the electronic apparatus, execute step S215 for deciding an effective range according to the effective location and a second sensitivity range of the second UE by the electronic apparatus, and execute step S217 for updating the coverage hole by the effective range by the electronic apparatus.

In some embodiments, before executing the aforesaid steps S201 to S217, the coverage hole detection method may further execute a step for determining that an RSRP of the first UE is smaller than a first threshold by the electronic apparatus and another step for determining that the first UE does not perform a handover procedure by the electronic apparatus. In some embodiments, the coverage hole detection method may further execute a step for deciding a type of the coverage hole according to an RSSI of the first UE and a second threshold by the electronic apparatus.

In addition to the aforesaid steps, the second embodiment can also execute all the operations and steps of the first embodiment, have the same functions, and deliver the same technical effect as the first embodiment. How the second embodiment executes these operations and steps of the first embodiment, have the same functions, and deliver the same technical effect as the first embodiment will be readily appreciated by those of ordinary skill in the art based on the explanation of the first embodiment, and thus will not be further described herein.

A third embodiment of the present invention is a coverage hole detection method and a flowchart diagram of which is shown in FIG. 3. The coverage hole detection method is for use in an electronic apparatus, e.g., the coverage hole detection apparatus 11 described in the first embodiment.

Firstly, step S301 is executed to receive a first time length, a second time length, a third time length, a piece of first location information, and a piece of second location information by the electronic apparatus. The first time length is from a time point when a first UE has detected a disconnection from a first base station to a time point when the first UE determines that an RLF has happened. The second time length is from a time point when the first UE receives an RLF report request from a second base station to a time point when the first UE transmits an RLF report response to the second base station. The third time length is from a time point when the first UE has found the second base station through searching to a time point when the first UE has completed a radio link re-establishment procedure with the second base station. The first piece of location information indicates a location where the first UE determines that the RLF has happened. The piece of second location information indicates a location where the first UE transmits the RLF report response.

Then, step S302 is executed by the electronic apparatus to determine whether a sum of the first time length, the second time length, and the third time length is smaller than a preset time length. If the step S302 determines that the sum of the first time length, the second time length, and the third time length is smaller than a preset time length, the coverage hole detection method then continues to execute the steps S203 to S211. If the step S302 determines that the sum of the first time length, the second time length, and the third time length is not smaller than a preset time length, the coverage hole detection method is ended directly.

In addition to the aforesaid steps, the third embodiment can also execute all the operations and steps of the first and the second embodiments, have the same functions, and deliver the same technical effect as the first and the second embodiments. How the third embodiment executes these operations and steps of the first and the second embodiments, have the same functions, and deliver the same technical effect as the first and the second embodiments will be readily appreciated by those of ordinary skill in the art based on the explanation of the first and the second embodiments, and thus will not be further described herein.

A fourth embodiment of the present invention is a coverage hole detection method and a flowchart diagram of which is shown in FIG. 4. The coverage hole detection method is for use in an electronic apparatus, e.g., the coverage hole detection apparatus 11 described in the first embodiment.

Firstly, step S201 is executed to receive a first time length, a second time length, a piece of first location information, and a piece of second location information by the electronic apparatus. The first time length is from a time point when a first UE has detected a disconnection from a first base station to a time point when the first UE determines that an RLF has happened. The second time length is from a time point when the first UE receives an RLF report request from a second base station to a time point when the first UE transmits an RLF report response to the second base station. The piece of first location information indicates a location where the first UE determines that the RLF has happened. The piece of second location information indicates a location where the first UE transmits the RLF report response.

Then, step S401 is executed by the electronic apparatus to calculate a third distance according to the first piece of location information and the piece of second location information. Then, step S402 is executed by the electronic apparatus to determine whether the third distance is smaller than a coverage radius of a base station (e.g., the first base station). If the step S402 determines that the third distance is smaller than the coverage radius, the coverage hole detection method continues to execute the steps S203 to S211. If the step S402 determines that the third distance is not smaller than the coverage radius, the coverage hole detection method is ended directly.

In addition to the aforesaid steps, the fourth embodiment can also execute all the operations and steps of the first to the third embodiments, have the same functions, and deliver the same technical effect as the first to the third embodiments. How the fourth embodiment executes these operations and steps of the first to the third embodiments, have the same functions, and deliver the same technical effect as the first to the third embodiments will be readily appreciated by those of ordinary skill in the art based on the explanation of the first to the third embodiments, and thus will not be further described herein.

It shall be appreciated that the terms "first" and "second" used in "the first preset time length" and "the second preset time length" are used only to distinguish these different preset time lengths in the specification and the claims of the present invention. Likewise, the terms "first," "second," and "third" used in "the first distance," "the second distance," and "the third distance" are used only to distinguish these different distances. The terms "first" and "second" used in "the first boundary location" and "the second boundary location" are used only to distinguish the different boundary locations. The terms "first" and "second" used in "the piece of first location information" and "the piece of second location information" are used only to distinguish the different pieces of location information. The terms "first" and "second" used in "the first threshold" and "the second threshold" are used only to distinguish these different thresholds.

According to the description of the aforesaid embodiments, a first time length (i.e., a time length from a time point when a UE has detected a disconnection from a first base station to a time point when the UE determines that an RLF has happened) and a piece of first location information (i.e., the location where the UE determines that the RLF has happened) are used to calculate a first boundary location (i.e., a location where the UE has detected the disconnection between the UE and the first base station). Moreover, a second time length (i.e., a time length from a time point when the UE receives an RLF report request from a second base station to a time point when the UE transmits an RLF report response to the second base station) and a piece of second location information (i.e., a location where the UE transmits the RLF report response) are used to calculate a second boundary location (i.e., a location where the second base station is detected by the UE). Then, a coverage hole is decided according to the first boundary location, the second boundary location, and a sensitivity range of the UE.

Since the first boundary location corresponds to the location where the UE has detected a disconnection between the UE and the first base station and the second boundary location corresponds to the location where the second base station is detected by the UE, the coverage hole decided according to these two boundary locations and the sensitivity range of the UE is surely an area where it is impossible or difficult for the UE to be served by a base station. Additionally, the reference time information and the geographic information may also be used to derive the coverage hole more correctly.

The above disclosure is related to the detailed technical contents and inventive features thereof. People skilled in this field may proceed with a variety of modifications and replacements based on the disclosures and suggestions of the invention as described without departing from the characteristics thereof. Nevertheless, although such modifications and replacements are not fully disclosed in the above descriptions, they have substantially been covered in the following claims as appended.

What is claimed is:

1. A coverage hole detection apparatus, comprising:

a transceiver interface, being configured to receive a first time length, a second time length, a piece of first location information, and a piece of second location information, wherein the first time length is from a time point when a first user equipment (UE) has detected a disconnection from a first base station to a time point when the first UE determines that a Radio Link Failure (RLF) has happened, the second time length is from a time point when the first UE receives an RLF report request from a second base station to a time point when the first UE transmits an RLF report response to the second base station, the piece of first location information indicates a location where the first UE determines that the RLF has happened, and the piece of second location information indicates a location where the first UE transmits the RLF report response; and

a processing unit, being electrically connected to the transceiving interface and configured to calculate a first distance according to the first time length and a moving velocity, calculate a second distance according to the second time length and the moving velocity, decide a first boundary location of a coverage hole according to the piece of first location information and the first distance, decides a second boundary location according to the piece of second location information and the second distance, and decide the coverage hole according to the first boundary location, the second boundary location, and a first sensitivity range of the first UE.

2. The coverage hole detection apparatus of claim **1**, wherein the transceiving interface further receives an effective location of a second UE, the processing unit further decides an effective range according to the effective location and a second sensitivity range of the second UE, and the processing unit further updates the coverage hole by the effective range.

3. The coverage hole detection apparatus of claim **1**, wherein the transceiving interface further receives a third time length, the third time length is from a time point when the first UE has found the second base station through searching to a time point when the first UE has completed a radio link re-establishment procedure with the second base station, and the processing unit further determines that a sum of the first time length, the second time length, and the third time length is smaller than a preset time length.

4. The coverage hole detection apparatus of claim **1**, wherein the first base station has a coverage radius, the processing unit further calculates a third distance according to the piece of first location information and the piece of second location information, and the processing unit further determines that the third distance is smaller than the coverage radius.

5. The coverage hole detection apparatus of claim **1**, wherein the processing unit further determines that a Reference Signal Receiving Power (RSRP) of the first UE is smaller than a first threshold and determines that the first UE does not perform a handover procedure.

6. The coverage hole detection apparatus of claim **5**, wherein the processing unit further decides a type of the coverage hole according to a Received Signal Strength Indicator (RSSI) of the first UE and a second threshold.

7. A coverage hole detection method for use in an electronic apparatus, comprising:

receiving a first time length, a second time length, a piece of first location information, and a piece of second location information, wherein the first time length is from a time point when a first UE has detected a disconnection from a first base station to a time point when the first UE determines that an RLF has happened, the second time length is from a time point when the first UE receives an RLF report request from a second base station to a time point when the first UE transmits an RLF report response to the second base station, the piece of first location information indicates a location where the first UE determines that the RLF has happened, and the piece of second location information indicates a location where the first UE transmits the RLF report response;

calculating a first distance according to the first time length and a moving velocity;

calculating a second distance according to the second time length and the moving velocity;

deciding a first boundary location of a coverage hole according to the piece of first location information and the first distance;

deciding a second boundary location according to the piece of second location information and the second distance; and deciding the coverage hole according to the first boundary location, the second boundary location and a first sensitivity range of the first UE.

8. The coverage hole detection method of claim **7**, further comprising:

receiving an effective location of a second UE;

deciding an effective range according to the effective location and a second sensitivity range of the second UE; and

updating the coverage hole by the effective range.

9. The coverage hole detection method of claim **7**, further comprising:

receiving a third time length, wherein the third time length is from a time point when the first UE has found the second base station through searching to a time point when the first UE has completed a radio link re-establishment procedure with the second base station; and

determining that a sum of the first time length, the second time length, and the third time length is smaller than a preset time length.

10. The coverage hole detection method of claim **7**, wherein the first base station has a coverage radius, the coverage hole detection method further comprises:

calculating a third distance according to the piece of first location information and the piece of second location information; and

determining that the third distance is smaller than the coverage radius.

11. The coverage hole detection method of claim **7**, further comprising:

determining that an RSRP of the first UE is smaller than a first threshold; and

determining that the first UE does not perform a handover procedure.

12. The coverage hole detection method of claim **11**, further comprising:

deciding a type of the coverage hole according to an RSSI of the first UE and a second threshold.

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